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Abstract

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OPTICAL ABSORPTION OF POLYCRYSTALLINE CdS LAYERS

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The present communication sets forth the results of studies of the optical absorption of polycrystalline layers of cadmium sulfide. The layers were obtained by evaporating powder onto an insulating substrate (glass, quartz) in vacuum, in an atmosphere of argon, and in hydrogen sulfide. According to the experimental conditions, the substrate could be heated from room temperature to 550°. The powder evaporator, as well as the substrate heater, were placed outside the volume in which the films were deposited. In the course of the work more than 600 specimens were prepared, for which the thicknesses d and the optical density kd were measured in the wavelength range from 0.185 to 2.5 μ.

Figures 1 and 2 present the absorption spectra of cadmium sulfide films obtained by evaporation in vacuum, H_2S, and argon onto a substrate which at the beginning of deposition was at room temperature, 350 and 450°. As is seen from the figures, the absorption spectra of polycrystalline cadmium sulfide layers have a complex form. For some films it was not possible to measure the optical density in certain parts of the spectrum, since the sensitivity of the instrument was insufficient. These parts of the curves are indicated by dashed lines.

For the majority of the specimens studied by us, the absorption was measured beginning at λ 250 mμ. For some specimens it was possible to measure the absorption also in a still shorter-wavelength region of the spectrum. Such films have a maximum on the absorption curve at λ 230 mμ. Their absorption in the visible region amounts to several percent of the absorption in the ultraviolet. This type of spectrum was also observed in other works ([1,2]). It is necessary to point out that, for some of the films deposited on cover glasses, the absorption maximum occurred not at λ 230 mμ, but at λ 250 or 270 mμ. For some specimens the absorption in the region 250–400 mμ is large and comparable with the absorption in the region of 230 mμ. The curves for some specimens are similar in shape to the absorption curves of single crystals.

Figures 1 and 2 show absorption spectra for films whose thickness is approximately the same. Nevertheless, in the region 300–550 mμ the specimens are characterized by different magnitudes of absorption. This means that such absorption is not intrinsic. It can be due only to an impurity. A change in the

Figure 1

Figure 1: Figure 1

Figure 2

Figure 2: Figure 2

concentration of the latter leads to a change in the magnitude of the absorption. The method of preparing the layers in our case permits us to assert that no foreign impurity was introduced into the cadmium sulfide films; consequently, it could appear only in the process of preparing the specimen.

Upon heating, as is known, cadmium sulfide sublimes, and its vapors possess a high degree of dissociation (^{3}). This decomposition process depends on temperature: at 800° the cadmium sulfide vapors are dissociated by 20%, and at 1100° already by 96%. Thus, during sublimation in the atmosphere above solid sulfide there are both CdS molecules and free

Fig. 1. **a** –absorption spectra of CdS films deposited in vacuum on a substrate at room temperature: film No. 29 –thickness $d = 5.0 \cdot 10^{-6}$ cm; No. 118 –$d = 5.4 \times 10^{-5}$ cm; No. 166 –$d = 6.0 \cdot 10^{-6}$ cm; No. 172 –$d = 4.0 \cdot 10^{-5}$ cm; No. 178 –$d = 1.1 \cdot 10^{-5}$ cm. **b** –absorption spectra of CdS films deposited in vacuum on a substrate heated to 450°: No. 258 –$d = 2.3 \cdot 10^{-4}$ cm; No. 268 –$d = 3.6 \cdot 10^{-5}$ cm; No. 270 –$d = 6.1 \cdot 10^{-5}$ cm; No. 280 –$d = 2.0 \cdot 10^{-6}$ cm; No. 284 –$d = 2.7 \cdot 10^{-5}$ cm; No. 294 –$d = 5.4 \cdot 10^{-6}$ cm.

Fig. 2. **a** –absorption spectra of CdS films deposited in argon on a substrate at room temperature: No. 348 –$d = 1.1 \cdot 10^{-4}$ cm; No. 370 –$d = 1.5 \cdot 10^{-5}$ cm; No. 386 –$d = 1.3 \cdot 10^{-4}$ cm; No. 408 –$d = 4.5 \cdot 10^{-5}$ cm. **b** –absorption spectra of CdS films deposited in argon and H_2S on a substrate heated to 350°: No. 417 –$d = 6.9 \cdot 10^{-5}$ cm; No. 445 –$d = 5.4 \cdot 10^{-5}$ cm; No. 467 –$d = 6.8 \cdot 10^{-6}$ cm; No. 469 –$d = 1.0 \cdot 10^{-6}$ cm; heated to 450°: No. 509 –$d = 1.8 \cdot 10^{-4}$ cm; No. 518 –$d = 9.20 \cdot 10^{-5}$ cm; No. 610 –$d = 1.0 \cdot 10^{-4}$ cm.

cadmium atoms (4) and diatomic sulfur. When the layer is deposited, these particles, settling on the substrate, will be partially reflected from it; and if one of the components of the deposited substance is reflected in greater amount, then the stoichiometric composition of such a sublimed layer will be disturbed. Since the melting temperature of sulfur is considerably lower than that of cadmium, sulfur will be reflected from the substrate in greater amount, and the polycrystalline layers will be enriched, relative to the stoichiometric composition, with excess cadmium atoms. These atoms also play the role of an impurity.

The process of stoichiometry disturbance can be intensified by changing the substrate temperature. In our experiments it was heated to 450°. However, as measurements showed, even a substrate at room temperature is heated during the process of depositing the film. Its heating is caused by radiation from the evaporator, as well as by hot particles of the sublimed substance. In the case of depositing a layer in vacuum, the final temperature of the substrate reached 40–170°, and in an argon atmosphere 160–300°. Therefore, samples whose preparation began even at room temperature of the substrate must contain different amounts of excess cadmium. This conclusion is confirmed by the fact that the absorption spectra of films deposited on a hot substrate (Figs. 1b and 2b) are similar to the spectra of low-temperature samples (Figs. 1a and 2a).

Thus, specimens prepared both in vacuum and in an atmosphere of argon and hydrogen sulfide have a complex, but similar in appearance, absorption spectrum. Consequently, the nature of the absorption in them is one and the same. All films whose absorption was measured down to 200 mμ have a maximum at $\lambda = 230$ mμ; therefore it should be attributed to intrinsic absorption. In the region 300–550 mμ the absorption differs among different samples. Here a number of maxima are observed, corresponding to $\lambda\lambda$ 320, 420, and 490 mμ, which appear differently. In some samples they are present in a hidden form; in others they are sharply expressed. As we have already indicated, such absorption may be impurity absorption, caused by excess cadmium atoms.

Absorption of light by impurity centers, as is known, can occur in two ways. As a result of absorption of the exciting light, an electron from the energy level of the impurity can be transferred into the conduction band. In this case the impurity absorption will consist of a band with one maximum. In addition, absorption of light can occur within the impurity center, bringing this center into an excited state. Such an impurity, depending on its energy structure, will give rise to one or several bands of additional absorption.

The presence in cadmium sulfide of several absorption bands belonging to excess cadmium atoms indicates the second mechanism of impurity absorption. Thus, the absorption of cadmium sulfide in the region 300–520 mμ is determined mainly by the absorption of excess cadmium atoms, in which electrons are transferred by the energy of the exciting light from normal levels to excitation levels. Therefore, in accordance with the absorption spectrum, an excess cadmium atom in the CdS lattice must have three energy levels of excitation: 3.85, 2.94, and 2.52 eV. The energy levels of an impurity are usually located in the forbidden band; consequently, for cadmium sulfide it must be much greater than 2.4 eV. Most likely, it corresponds to absorption at $\lambda = 230$ mμ and is equal to 5.36 eV.

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Note: Figure translations are in progress. See original paper for figures.